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955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Consumables Affecting Extended CSM Lifetime in Lunar Orbit Case 320

DATE: December 31, 1968

FROM: A. S. Haron
R. D. Raymond

ABSTRACT

A preliminary analysis was made of the effect of consumables on CSM lunar orbit lifetime for a contingency in lunar orbit. Calculations based on data from Apollo 8 consumables analysis reports and the spacecraft data book indicate a contingency operating time of about one week at nominal lunar orbit usage rates. This time can be extended to approximately two weeks by adding LiOH cannisters and powering down to a minimum power three-fuel-cell configuration. A single-fuel-cell powered down configuration might extend the capability somewhat, but even at minimum power the system is limited by the cryogenic supply to about three weeks.

(NASA-CR-104044) CONSUMABLES AFFECTING EXTENDED CSM LIFETIME IN LUNAR ORBIT (Bellcomm, Inc.) 11 p

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MEMORANDUM FOR FILE

PURPOSE

An analysis was made of the effect of consumables usage on CSM contingency lunar-orbit lifetime.

SUMMARY

Preliminary calculations based on data from the Apollo 8 consumables analysis and the spacecraft data book are summarized in Table 1 and Figures 1 and 2.[1,2] The basic assumption made is that the consumables available for lunar orbit contingency are those nominally remaining at TEI in reference 1.

The additional survival time in lunar orbit will be approximately <u>one week</u> if operations are continued at the nominal lunar orbit rates. The first constraint is LiOH depletion, which occurs nominally about TEI + 96 hours. The LiOH can be conserved up to about 148 hours by less frequent changes.

If the LiOH constraint is removed by adding canisters and the CSM is powered down to the minimum level to maintain three fuel cells in operation (~1200 watts), the lifetime can be extended to about <u>two weeks.</u>

In either of the above two methods it is assumed that attitude control is maintained to optimize water requirements for thermal control. At the power levels assumed, 2200 watts and 1200 watts, this appears to be feasible.

An ultimate limit with respect to cryogenics and power is reached in a little over three weeks at the minimum single fuel cell rate of about 400 watts. This method does not appear as feasible, because considerable LiOH additions are required, attitude orientation is required, and the necessary systems may not be available at this low power level.

DISCUSSION

1. Consumables remaining at TEI.

   a. Based on reference 1:

      H_2 35.1 lbs (58.4 lbs loaded)

      O_2 433.6 lbs (653 lbs loaded)

      Water 53 lbs in both tanks (based on radiator α=.356)
      SM RCS 1068.3 lbs (1362.4 lbs loaded)

   b. Based on reference 2:

      LiOH 8 cannisters (∿16 required for mission)

2. EPS and ECS Cryogenic Consumption:

   a. The nominal source power during lunar orbit is approximately 2200 watts (∿77 amps from the fuel cells).

   b. The minimum power for a drifting flight configuration is about 1500 watts. This might be lowered to the minimum required to maintain three fuel cells on line (temperature limited to 380° F minimum), which requires about 1200 watts (based on reference 2).

   c. At least one fuel cell must be used, resulting in a minimum source power of 400 watts in order to maintain fuel cell minimum temperature.

   d. The ECS oxygen rates are based on reference 1:

1)	Metabolic	0.229 lb/hr
2)	Cabin leakage	0.2 lb/hr
3)	Water tank purge	0.032 lb/hr
4)	Waste Management	0.024 lb/hr
	Total	0.485 lb/hr

   e. Table 1 shows the resulting H_2 and O_2 time limits based on the above EPS and ECS requirements.

3. LiOH Canisters:

Normal canister replacement is one canister every 12 hours, with two canisters used in parallel. The resulting usage is 2 cans per day. Reference 2 indicates a possibility of two cans lasting for 37 hours, which could extend the usage. Even with this extension it would be necessary to load extra canisters before flight to appreciably extend the mission.

It is assumed that 16 replacement canisters are required for the nominal mission. At least 26 canisters are needed if the mission is expected to be extended up to two weeks past TEI.

4. SM RCS Propellant:

The attitude control system must be used to avoid serious water constraints. If it is assumed that propellant utilization is continued at the nominal lunar orbit rate for attitude hold (1.2 lbs/hr. from reference 1) this is not a limiting constraint. About 890 hours of control are available with attitude hold only.

5. Water:

Under the nominal power level 2200 watts in lunar orbit, with the ECS radiator solar absorptance degraded to 0.356, Figure 5-3 (b) of Reference (1) indicates a net water depletion rate of approximately 0.1 lbs/hr. With 53 lbs of water remaining in the tanks at the time of failure to achieve TEI, it will take 530 hours in lunar orbit before the water is completely depleted.

Under the intermediate power level of 1200 watts, the fuel cell water production rate will be reduced by 0.79 lbs/hr., but simultaneously the need for boiling 1.60 lbs/hr. of water to supplement the radiator heat rejection will be eliminated. Thus, the net result will be a water surplus at the rate of 0.72 lbs/hr. Conceivably, this surplus water can be used to initially fill the tanks to their 92 lbs capacity over a period 54 hours, followed by dumping of the excess water generated.

Under the lowest power level of 400 watts, the accumulation of water surplus will occur at the slower rate

0.09 lbs/hr. Thus, it will take 434 hours to fill the tanks prior to the initiation of water dumping.

To summarize, there appears to be no water constraint on survival duration in lunar orbit under reasonably expected power levels. The other consumables needed for survival will be depleted much earlier than the water.

Figure (2) shows a plot of the water quantity as a function of time and power level.

ADDITIONAL RESEARCH

A more comprehensive study of similar circumstances was performed by Tom Bottomley early in the program (reference 3). This report indicates survival times in lunar orbit of the same magnitude estimated here.

CONCLUSION

With no specific survival extension preplanning it appears that survival time in lunar orbit is about one week after TEI time. This could be extended to about two weeks with added provisions and subsystem operation planning. The feasibility of extending the survival time to as much as three weeks cannot be confirmed at this time.

A. S. Haron

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Attachments
References
Table 1

TABLE 1. OXYGEN AND HYDROGEN

Average Source Load (Watts)	O_2		H_2		H_2O			
					α Radiator = 0.2		α Radiator = 0.356	
	Rate (Lb/Hr)	After TEI Life (Hrs.)	Rate (Lb/Hr.)	After TEI Life (Hrs.)	Rate of Depletion (Lb/Hr.)	Life After TEI Failure (Hrs.)	Rate of Depletion (Lb/Hr.)	Life After TEI Failure (Hrs.)
2200 W [~ 77 amps (F/C)] (continue nominal)	2	216	0.19	185	-0.2**	∞	+0.1	530
1200 W [~ 41 amps (3 F/C @ Min. Load)	1.3	335	0.105	335	**	∞	-0.72**	∞
400 W [~ 13.6 amps (F/C)] (1 F/C @ Min. Load)	0.79	550	0.035	1000	**	∞	- 0.09**	∞

H_2O at TEI (α Rad = 0.2) : 77 Lbs.

(α Rad = 0.356): 53 Lbs.

O_2 at TEI = 433.6 Lbs.

H_2 at TEI = 35.1 Lbs

*Includes 0.485 lbs/hr ECS usage.

**Accumulation

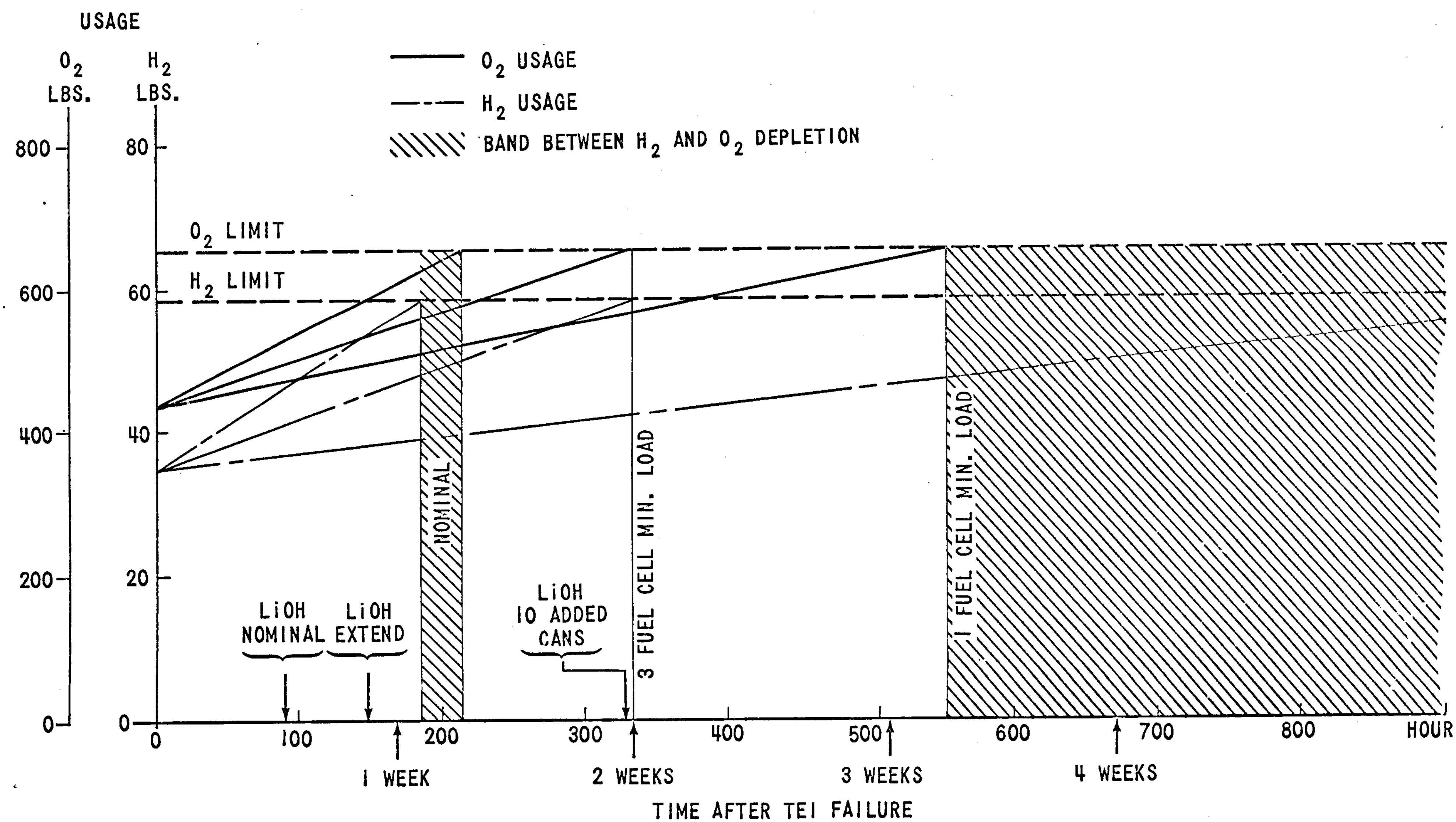

FIGURE 1 - CSM EXTENDED LIFE AFTER TEI FAILURE

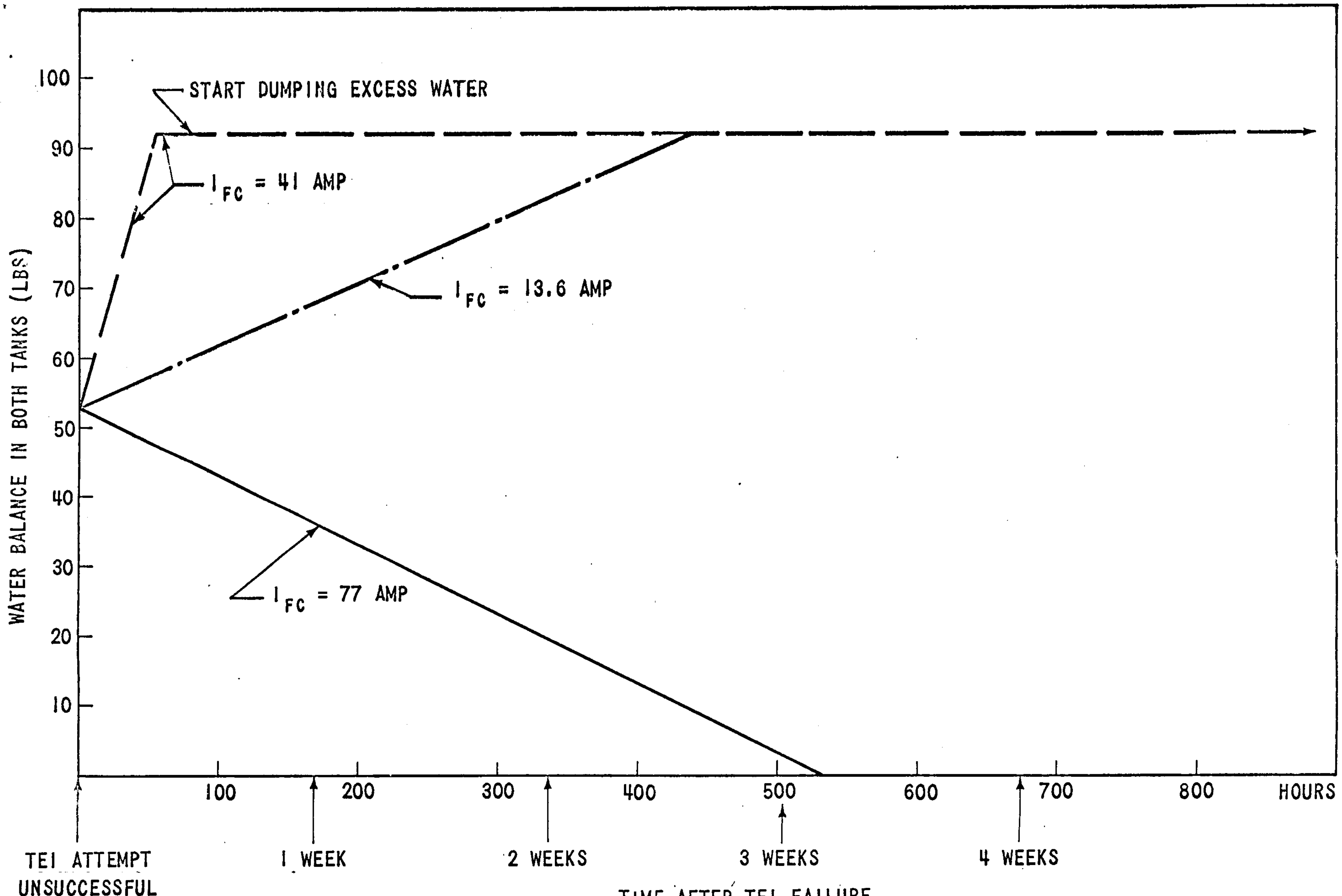

FIGURE 2 - CSM WATER BALANCE IN LUNAR ORBIT

REFERENCES

1. MSC Internal Note No. 68-FM-278, Consumables Analysis for the Apollo 8 Spacecraft Operational Trajectory, MSC, Houston, Texas, November 18, 1968.

2. NASA SNA-8-D-027(I) Rev.1, CSM/LM Spacecraft Operational Data Book, MSC, Houston, Texas, November 1, 1968.

3. Bottomley, T. A., Jr., Review of Life Support Design and Consumables Supplies Related to Survival and Rescue of Apollo Crewmen, Memorandum for File, Bellcomm, Inc., December 16, 1964

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